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RESEARCH REPORT

(20)

RESEARCH PROJECT NM 12 01 11
Subtask 5 Report No. 3

THE RATE AND MAGNITUDE OF EXPLOSIVE DECOMPRESSION REQUIRED TO PRODUCE LETHAL EFFECTS IN ALBINO RATS

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Bureau of Medicine and Surgery
Research Report NM 12 01 11, Subtask 5
Report No. 3

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31 January 1957

SUMMARY PAGE

THE PROBLEM

These tests were designed to determine the effect of faster rates of explosive decompression on Albino Rats. One control group was taken from sea level to 40,000 feet, another group from sea level to 69,000 feet, and another from sea level to 105,000 feet in 0.53, 0.9, and 1.11 seconds respectively. One experimental group of rats was taken from sea level to 40,000 feet, another group from sea level to 69,000 feet, and another group from sea level to 105,000 feet in 0.0043, 0.0068, and 0.0075 second respectively.

FINDINGS

None of the control rats were killed; 40%, 70%, and 70% of the rats explosively decompressed from sea level to 40,000, 69,000, and 105,000 feet respectively died as a result of the experimental procedure.

ACKNOWLEDGMENT

Grateful acknowledgment is extended to Lynn A. Alford, HM 1, USN, and A. T. Layne, EMC, USN.

INTRODUCTION

The occurrence of pulmonary lesions following explosive decompression has been reported by Smith, Corey, Bert, Hall, Lewis and Haymaker, Edelman and coworkers, and Livingston and his coworkers (1-8). These lesions may vary from small petechiae to gross hemorrhage depending upon the rate (2, 5) and range of explosive decompression (5), the volume of gas in the lung (2), the frequency of re-exposure (8), and the length of time at altitude (3). Corey (2) has noted that the reduction of pulmonary volume by taping the chest results in less severe symptoms.

The present report is a comparison of the effects on the pulmonary system of explosive decompression at various rates and over various ranges. These experiments were designed to test Sweeney's (9) hypothesis that some finite time is required for elastic tissue, represented by the alveolar walls, to elongate.

METHODS AND PROCEDURE

A 14-1/4 inch diameter parasite chamber (Figure 1) was constructed and attached to a 980 cubic foot reservoir. A 14-1/4 inch paper diaphragm separating them could be ruptured by means of a four-bladed knife fired with a carbon-dioxide gun.

Wistar strain rats approximately twelve weeks of age were used as experimental animals. No restriction was made on food or water prior to the explosive decompression. All rats were pre-oxygenated for one-half hour before the decompression. Forty-five rats in all were used in this exploratory experiment.

Three control groups of five rats each were explosively decompressed from sea level to a simulated altitude of 40,000 feet in 0.53 second; from sea level to 69,000 feet in 0.9 second; and from sea level to 105,000 feet in 1.11 second. All control groups remained above 18,000 feet for five seconds or less. Ten rats were explosviely decompressed from sea level to 40,000 feet in 0.0043 second and recompressed to 18,000 feet in less than two seconds. Total time from sea level to 40,000 feet and back to sea level was eleven seconds. Ten rats were explosively decompressed from sea level to 69,000 feet in 0.0068 second and recompressed to 18,000 feet in less than two seconds. Total time was fourteen seconds. Ten rats were explosively decompressed from sea level to 105,000 feet in 0.0075 second and recompressed to 18,000 feet in less than two seconds (4). Total time was twenty-six seconds.

Table I

Pathological Results Observed in Control Groups of Rats Decompressed from Sea Level to Indicated Altitudes at Indicated Rates of Time*

Rat No.	Lungs	Heart	Liver	Oral and Nasal	Intestines
		Sea Level to 40,000 feet in 0.53 sec.			
CA1	Very slight petechiae No hemorrhage	N#	N	N	N
CA2	Normal. No hemorrhage	N	N	N	N
CA3	Very slight peripheral ecchymoses. No hemorrhage	N	N	N	N
CA4	Slight ecchymoses No hemorrhage	N	N	N	N
CA5	Normal. No hemorrhage	N	N	N	N
		Sea Level to 69,000 feet in 0.9 sec.			
CB1	Slight ecchymoses. Slight petechiae. No hemorrhage	Right auricle Slightly dilated	N	N	N
CB2	Very slight ecchymoses No hemorrhage	Moderately dilated right auricle	N	N	N
CB3	Moderate ecchymoses. Slight petechiae. No hemorrhage	N	N	N	N
CB4	Moderate petechiae. Slight peripheral ecchymoses. No hemorrhage	Slightly dilated right auricle	N	N	N
CB5	Slight ecchymoses. Moderate petechiae. No hemorrhage	N	N	N	N
		Sea Level to 105,000 feet in 1.11 sec.			
CC1	Slightly mottled. Slight ecchymoses. Slight petechiae.	N	N	N	N
CC2	Slightly mottled. Slight ecchymoses. Slight petechiae.	N	N	N	N
CC3	Slight ecchymoses. Slight hemorrhage. Slight petechiae.	Moderately dilated right auricle	Flukes	N	N
CC4	Slight petechiae. Slight ecchymoses. Slight hemorrhage	right auricle Slightly dilated	N	N	N
CC5	Moderate ecchymoses. Slight petechiae. No hemorrhage	Slightly dilated right auricle	N	N	Slight hemorrhage

*All rats were males approximately twelve weeks of age. All lungs floated and diaphragms appeared normal. Rats were sacrificed one hour after removal from the chamber.

#N = Normal

Table II

Pathological Results Observed in Experimental Groups of Rats Explosively Decompressed from Sea Level to Indicated Altitudes at Indicated Rates of Time*

Rat No.	Death	Lungs	Heart	Liver	Oral and Nasal	Intestines
		Sea Level to 40,000 feet in 0.0043 sec.				
EA1	+ 3 min.	Massive hemorrhage, light and dark red	N#	N	Epistaxis	Slight hemorrhage, small intestine
EA2	+ 5 min.	Massive hemorrhage, Ecchymoses and petechiae	N	Flukes	Frothing from nose	N
EA3	+ 6 min.	Moderate hemorrhage, Ecchymoses. Mottled lungs	N	N	Epistaxis	N
EA4	+ 6 min.	Massive hemorrhage, dark red	N	Flukes	Epistaxis	N
EA5	Sacrificed + 1 hr.	Moderate hemorrhage, Ecchymoses. Mottled lungs	Dilated right auricle	N	N	N
EA6	Sacrificed + 1 hr.	Mild hemorrhage, Ecchymoses Petechiae. Mottled lungs	N	N	N	N
EA7	Sacrificed + 1 hr.	Mild hemorrhage Ecchymoses Petechiae. Mottled lungs	N	N	N	N
EA8	Sacrificed + 1 hr.	Mild hemorrhage Ecchymoses Mottled lungs	N	N	N	N
EA9	Sacrificed + 1 hr.	Moderate hemorrhage Mottled lungs	N	N	N	N
EA10	Sacrificed + 1 hr.	Moderate hemorrhage, Ecchymoses. Petechiae, Mottled lungs	N	N	N	N
		Sea Level to 69,000 feet in 0.0068 sec.				
EB1	Immediate	Ecchymoses. Massive hemorrhage bright red	N	Flukes	Massive epistaxis (frothy dark red blood)	Slight hemorrhage small intestine
EB2	Immediate	Ecchymoses. Massive hemorrhage, dark red	N	Flukes	Massive epistaxis (frothy dark red blood)	Veins enlarged & full, large intest. Slight hemorrhage small intestine
EB3	Immediate	Ecchymoses. Massive hemorrhage, dull red	N	Flukes	Massive epistaxis (blood light in color)	N
EB4	Immediate	Ecchymoses Massive hemorrhage, dark red	N	Flukes	Massive epistaxis (blood light in color)	Slight hemorrhage, small intestine
EB5	Immediate	Massive hemorrhage, dark red	N	Flukes	Massive epistaxis (blood light in color)	Slight hemorrhage, small intestine
EB6	+ 7 min	Massive hemorrhage, dark red	N	N	Massive epistaxis (blood light in color)	N
EB7	+ 9 min.	Massive hemorrhage, dark red	N	N	Epistaxis	N
EB8	Sacrificed + 1 hr.	Ecchymoses, moderate hemmorhage Mottled lungs	N	Flukes	N	N
EB9	Sacrificed + 1 hr.	Ecchymoses. Moderate hemorrhage. Petechiae, Mottled lungs	N	Flukes	N	N
EB10	Sacrificed + 1 hr.	Ecchymoses Moderate hemorrhage. Mottled lungs	N	Fluke	N	N
		Sea Level to 105,000 feet in 0.0075 sec.				
EC1	Immediate	Massive hemorrhage, dark red	N	Flukes	Epistaxis	Veins appear full and large
EC2	Immediate	Ecchymoses. Moderate hemorrhage, bright red	N	N	Epistaxis	Hemorrhage, small intestine
EC3	Immediate	Ecchymoses. Massive hemorrhage, dark red	N	Flukes	Epistaxis	N
EC4	Immediate	Massive hemorrhage, dark red	Dilated right auricle	N	Epistaxis	Discoloration, small intestine
EC5	+ 9 min	Ecchymoses Massive hemorrhage, dark red	Dilated right auricle	N	Epistaxis	N
EC6	+ 11 min	Massive hemorrhage, dark red	N	Flukes	N	Slight hemorrhage, large intestine
EC7	+ 13 min	Ecchymoses Massive hemorrhage, dark red	N	Flukes	N	veins dilated
EC8	Sacrificed + 1 hr.	Ecchymoses, Moderate hemorrhage Mottled lungs	N	N	N	N
EC9	Sacrificed + 1 hr.	Ecchymoses, Moderate hemorrhage Petechiae, Mottled lungs	N	N	N	N
EC10	Sacrificed + 1 hr.	Ecchymoses Moderate hemorrhage Mottled lungs	N	N	N	N

* All rats were males approximately twelve weeks of age. All lungs floated, and the diaphragms appeared normal.

N. Normal

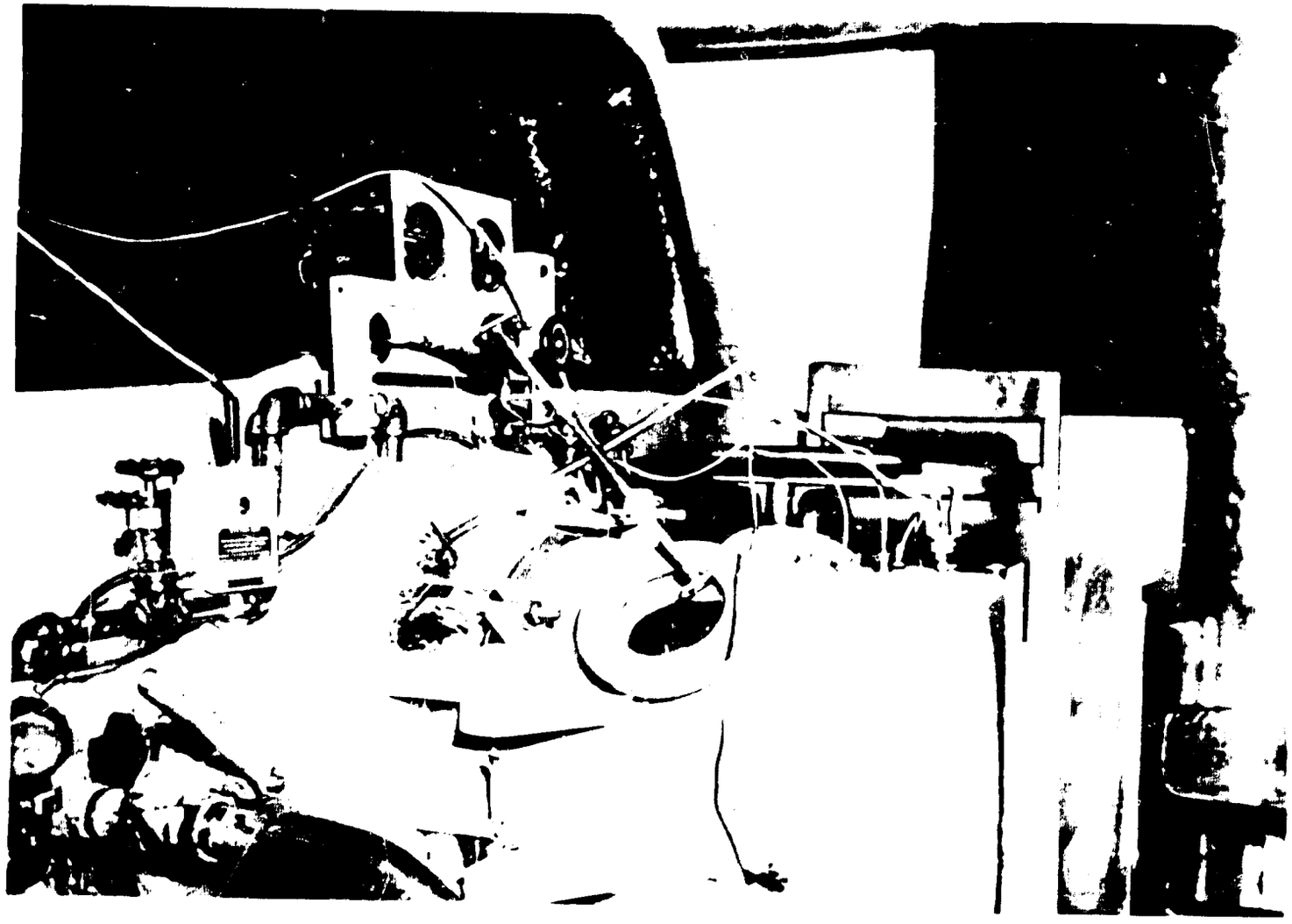

Figure 1

Animal Explosive Decompression Parasite Chamber
Four Bladed Diaphragm Cutting Knife Also Shown

Following exposure to the simulated terminal altitudes, control and experimental rats were returned to sea level and removed immediately from the chamber. The groups were allowed to remain undisturbed for one hour, after which time surviving rats were sacrificed and examined grossly for pathological changes to the respiratory, gastrointestinal, and cardiovascular systems.

RESULTS

Results are detailed in Tables I and II. No rat in any control group died as a result of the exposure. There was no evidence of gross hemorrhage in the lungs in the control group, but there were areas of ecchymoses and petechiae evident. All lungs floated. All hearts appeared normal with the exception of some dilation of the auricles. All gastrointestinal systems were normal when examined grossly, with the exception of one of the rats taken to 105,000 feet which exhibited a slight hemorrhage of the small intestine.

Of the ten rats explosively decompressed from sea level to 40,000 feet in 0.0043 s second (0.93×10^7 feet/sec, or 142,000 mm Hg/sec), four died at +3, +5, +6, and +6 minutes (after recompression to sea level). All four exhibited massive pulmonary hemorrhage and epistaxis. All hearts appeared to be normal; gastrointestinal systems were normal with the exception of a slight hemorrhage of the small intestine in the caecal area of one rat. The remaining six rats of this group were sacrificed and showed light to moderate hemorrhage of the pulmonary system but apparently normal hearts and gastrointestinal systems. The lungs of all these ten rats floated in water.

The second group of ten rats were explosively decompressed from sea level to 69,000 feet in 0.0068 second (1×10^7 feet/sec or 106,200 mm Hg/sec). Five of this group were dead on recompression to sea level, and two additional rats died at +7 and +9 minutes. All seven exhibited epistaxis, and four of the seven had some hemorrhage of the small intestine. The three rats which were sacrificed after an hour showed hemorrhage of the lungs; other systems appeared normal.

The third group of ten rats were explosively decompressed from sea level to 105,000 feet in 0.0075 second (1.4×10^7 feet/sec or 100,300 mm Hg/sec). Four of this group were dead on recompression, with three additional rats dead at +9, +11, and +15 minutes. All seven showed massive hemorrhage of the lungs; two had dilated auricles.

five exhibited epistaxis, and five had abnormalities of the vascular system in the intestinal area. The three rats sacrificed after an hour showed abnormalities of the pulmonary system, with other systems apparently normal.

DISCUSSION

The purpose of this experiment was to determine if there is a finite time required for the alveolar membranes to expand to point of rupture in explosive decompression. It was realized that a patent tracheal passage might allow rapid dissipation of prohibitive incipient pressure in the lungs no matter how rapid the onset of the pressure. If there is a minimal finite time required for expansion of alveolar tissue following explosive decompression, it must be less than 0.004 second for 100 per cent fatality in the rat.

The exposure times used in this experiment produced either lethal or sublethal effects in all rats. The probability is slight that all rats had a closed tracheal airway at the instant of decompression. The minimal symptoms seen in the control groups add credence to previous findings that the physical process of explosive decompression per se can produce pathological changes in the rat without the effects of hypoxia or decompression sickness (aerebullosis).

There was some similarity of symptoms in the group of rats exposed to 69,000 feet and the group exposed to 105,000 feet. The rate of change in pressure was similar (106,200 mm Hg/sec compared to 100,300 mm Hg/sec), but the ratio of gas expansion (RGE) would differ greatly. Sea level to 69,000 feet would give a ratio of gas expansion in dry air of 21.3, and sea level to 105,000 feet would give an RGE of 108.6 in dry air. RGE refers to free gas expansion; in explosive decompression, RGE would be opposed by pertinent tissue pressure. If the tissue can withstand a pressure change of 724.3 mm Hg (sea level to 69,000 feet), it apparently can tolerate 753 mm Hg change (sea level to 105,000 feet).

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